

instructions sent by the computer to the printer. **System software**, a class of software that includes the *operating system* and *utility programs*, handles these details and hundreds of other tasks behind the scenes.

What the Operating System Does

Every general-purpose computer today, whether it's a timesharing supercomputer or a laptop PC, depends on an **operating system (OS)** to keep hardware running efficiently and to make the process of communication with that hardware easier. Operating-system software runs continuously whenever your computer is on, providing an additional layer of insulation between you and the bits-and-bytes world of computer hardware. Because the operating system stands between the software application and the hardware, application compatibility is usually defined by the operating system, as well as by the hardware.

The operating system, as the name implies, is a system of programs that performs a variety of technical operations, from basic communication with peripherals to complex networking and security tasks.

- In order to support **multitasking**—the concurrent execution of multiple applications—the operating system creates dozens of processes (also called tasks). For example, there is usually at least one process associated with every window on the computer's screen. Because the CPU can execute only one process at a time, the operating system must do task scheduling, allocating blocks of CPU time to the processes to enable them to make progress.
- Modern operating systems manage **virtual memory**, which means the number of memory addresses is much larger than the amount of physical memory available. Virtual memory is divided into same-sized blocks called pages. When a process is not running on the CPU, its pages can be held temporarily on a hard disk. When a process is running, the pages containing the instructions and data needed by the CPU are brought into RAM, displacing pages used by an idle process.
- The operating system maintains the file system that keeps track of the location on the hard drive of all programs and data files.
- On multiuser systems, the operating system is responsible for **authentication** (determining that users are who they claim to be) and **authorization** (ensuring that users have permission to perform a particular action). An example of an authentication mechanism is requiring a user to enter a login name and password before using the computer. An example of an authorization mechanism is allowing only those with administrative privileges to install or uninstall application programs.

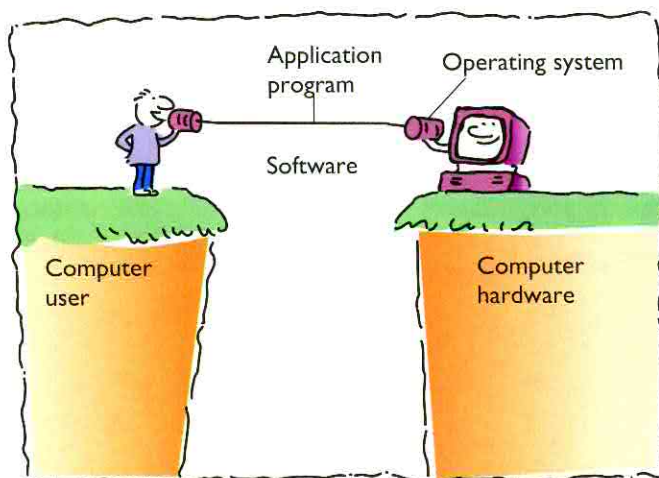
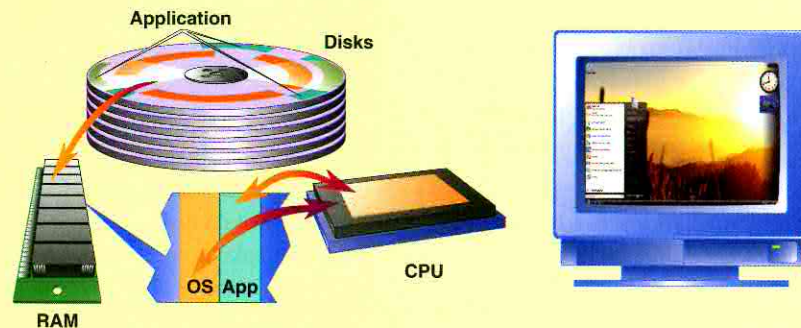


FIGURE 4.15 The user's view: When a person uses an application, whether a game or an accounting program, the person doesn't communicate directly with the computer hardware. Instead, the user interacts with the application, which depends on the operating system to manage and control hardware.

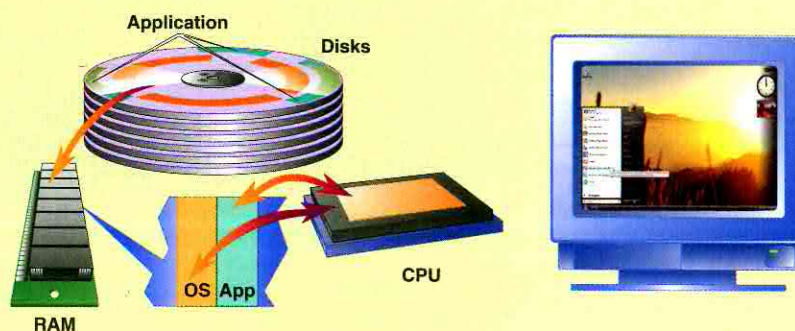
How It Works

4.2 The Operating System

Most of what you see on-screen when you use an application program and most of the common tasks you have the program perform, such as saving and opening files, are being performed by the operating system at the application's request.

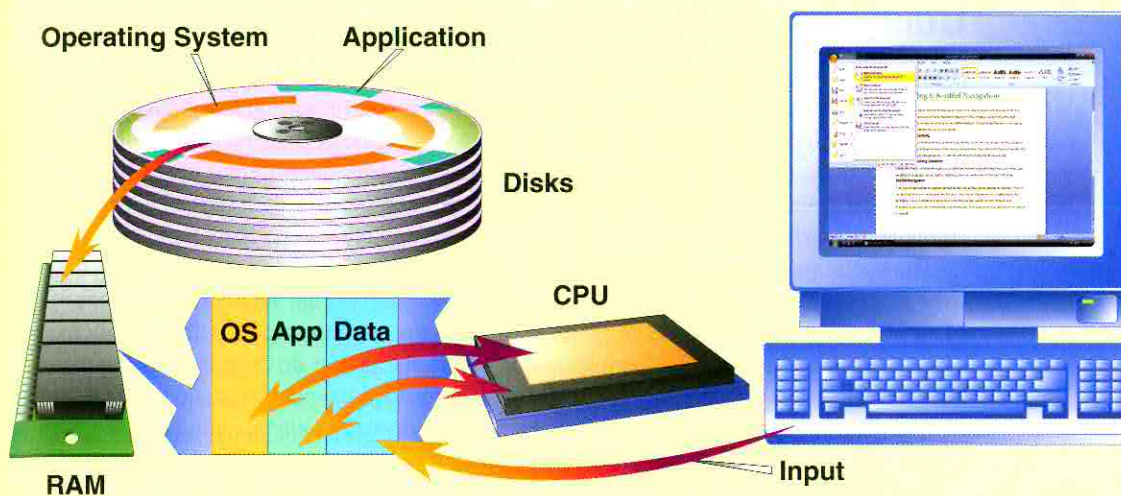


When a computer is turned off, there's nothing in RAM (random access memory), and the CPU isn't doing anything. The operating system (OS) programs must be in memory and running on the CPU before the system can function. When you turn on the computer, the CPU automatically begins executing instructions stored in ROM (read-only memory). These instructions help the system boot, and the operating system is loaded from disk into part of the system's memory.

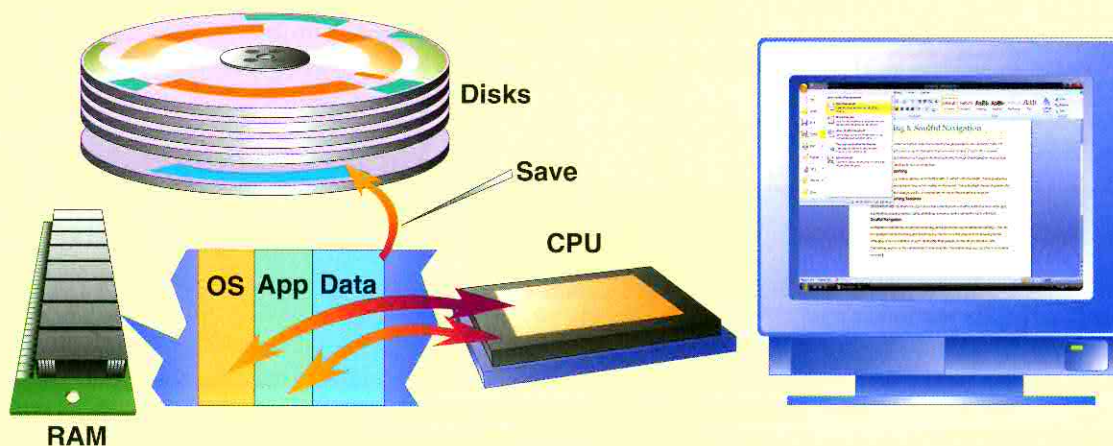


Using the mouse, you "ask" the operating system to load a word-processing application program into memory so it can run.

FIGURE 4.16



The loaded application occupies a portion of memory, leaving that much less for other programs and data. The OS remains in memory, so it can provide services to the application program, helping it to display on-screen menus, communicate with the printer, and perform other common actions. Because the OS and application are in constant communication, control—the location in memory where the CPU is reading program instructions—jumps around. If the application calls the OS to help display a menu, the application tells the CPU, “Go follow the menu display instructions at address x in the operating system area; when you’re done, return here and pick up where you left off.”



To avoid losing your data file when the system is turned off, you save it to the disk, meaning you have the OS write it into a file on the disk for later use. The OS handles communication between the CPU and the disk drive, ensuring that your file doesn't overwrite other information. (Later, when you reopen the file, the OS locates it on the disk and copies it into memory so the CPU—and, therefore, any program—can see it and work with it.)

Utility Programs and Device Drivers

Even the best operating systems leave some housekeeping tasks to other programs and to the user. **Utility programs** serve as tools for doing system maintenance and repairs that aren't automatically handled by the operating system. Utilities make it easier for users to copy files between storage devices, repair damaged data files, translate files so that different programs can read them, guard against viruses and other potentially harmful programs (as described in Chapter 10), compress files so they take up less disk space, and perform other important, if unexciting, tasks.

The operating system can directly invoke many utility programs, so they appear to the user to be part of the operating system. For example, **device drivers** are small programs that enable I/O devices—keyboard, mouse, printer, and others—to communicate with the computer. Once a device driver—say, for a new printer—is installed, the printer driver functions as a behind-the-scenes intermediary whenever the user requests that a document be printed on that printer. Some utility programs are included with the operating system. Others, including many device drivers, are bundled with peripherals. Still others are sold or given away as separate products.

Where the Operating System Lives

Some computers—mostly game machines, handheld computers, smart phones, and special-purpose computers—store their operating systems permanently in ROM (read-only memory) so they can begin working immediately when the user turns them on. But because ROM is

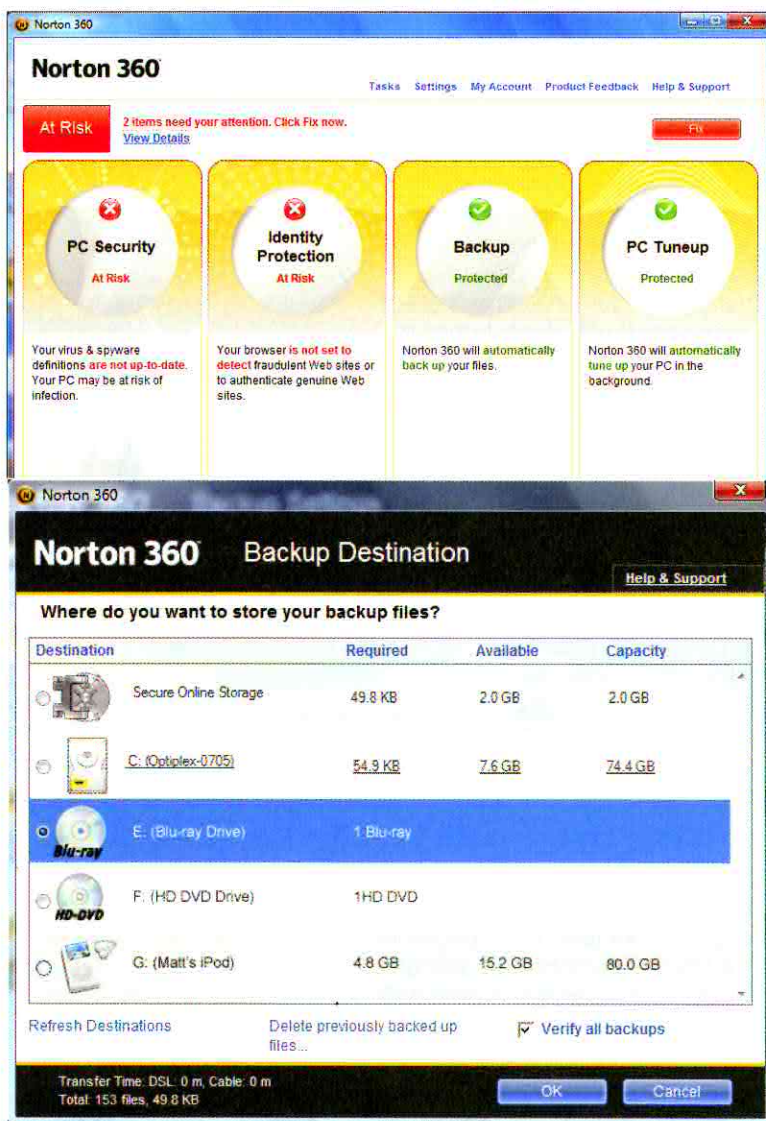


FIGURE 4.17 Norton 360 (above left) is a popular Windows utility package that includes software tools for protecting PCs from viruses, spyware, and other Internet risks. It also includes tools for disk backup and recovery (lower left). TechTool Pro (above) performs a variety of hardware and software diagnostic and repair functions for Mac OS.

unchangeable, operating systems on these machines can't be modified or upgraded without hardware transplants. Some computers, including many handheld devices, store their operating system in flash memory so it can be upgraded. But most computers, including all modern PCs, hold only a small portion of the operating system in ROM. The remainder of the operating system is loaded into memory in a process called **booting**, which occurs when you turn on the computer. (The term *booting* is used because the computer seems to pull itself up by its own bootstraps.)

Most of the time the operating system works behind the scenes, taking care of business without the knowledge or intervention of the user. But occasionally it's necessary for a user to communicate directly with the operating system. For example, when you boot a PC, the operating system takes over the screen, waiting until you tell it—with the mouse, the keyboard, or some other input device—what to do. If you tell it to open a graphics application, the operating system locates the program, copies it from disk into memory, turns the screen over to the application, and accepts commands from the application while you draw pictures on the screen.

Interacting with the operating system, like interacting with an application, can be anywhere from intuitive to challenging. It depends on something called the *user interface*. Because of its profound impact on the computing experience, the user interface is a critically important component of almost every piece of software.

The User Interface: The Human-Machine Connection

Early computer users had to spend tedious hours writing and debugging machine-language instructions. Later users programmed in languages that were easier to understand but still technically challenging. Today users spend much of their time working with preprogrammed applications, such as word processing that simulate and amplify the capabilities of real-world tools. As software evolves, so does the **user interface**—the look and feel of the computing experience from a human point of view.

The anthropologist Claude Levi-Strauss has called human beings **tool makers** and **symbol makers**. The user interface is potentially **the most sophisticated** of these constructions, one in which the **distinction between tool and symbol is blurred**.

—Aaron Marcus and Andries van Dam, *user interface experts*

Desktop Operating Systems

The earliest PC operating systems, created for the Apple II, the original IBM PC, and other machines, looked nothing like today's Mac and Windows operating systems. When IBM introduced its first personal computer in 1981, a typical computer monitor displayed 24 80-column lines of text, numbers, and/or symbols. The computer sent messages to the monitor telling it which character to display in each location on the screen. To comply with this hardware arrangement, the PC's dominant operating system, MS-DOS, was designed with a **character-based interface**—a user interface based on characters rather than on graphics.

MS-DOS (Microsoft Disk Operating System, often simply called DOS) became the standard operating system on IBM-compatible computers—computers functionally identical to IBM personal computers and, therefore, capable of running IBM-compatible software. Unlike the Windows desktop, MS-DOS used a **command-line interface** that required the user to type commands to which the computer responded. Some MS-DOS-compatible applications had a command-line interface, but it was more common for applications to

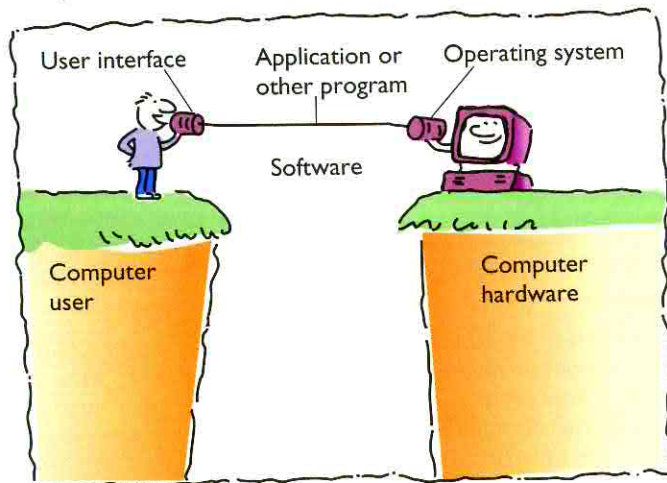


FIGURE 4.18 The user's view revisited: The user interface is the part of the computer system that the user sees. A well-designed user interface hides the bothersome details of computing from the user.

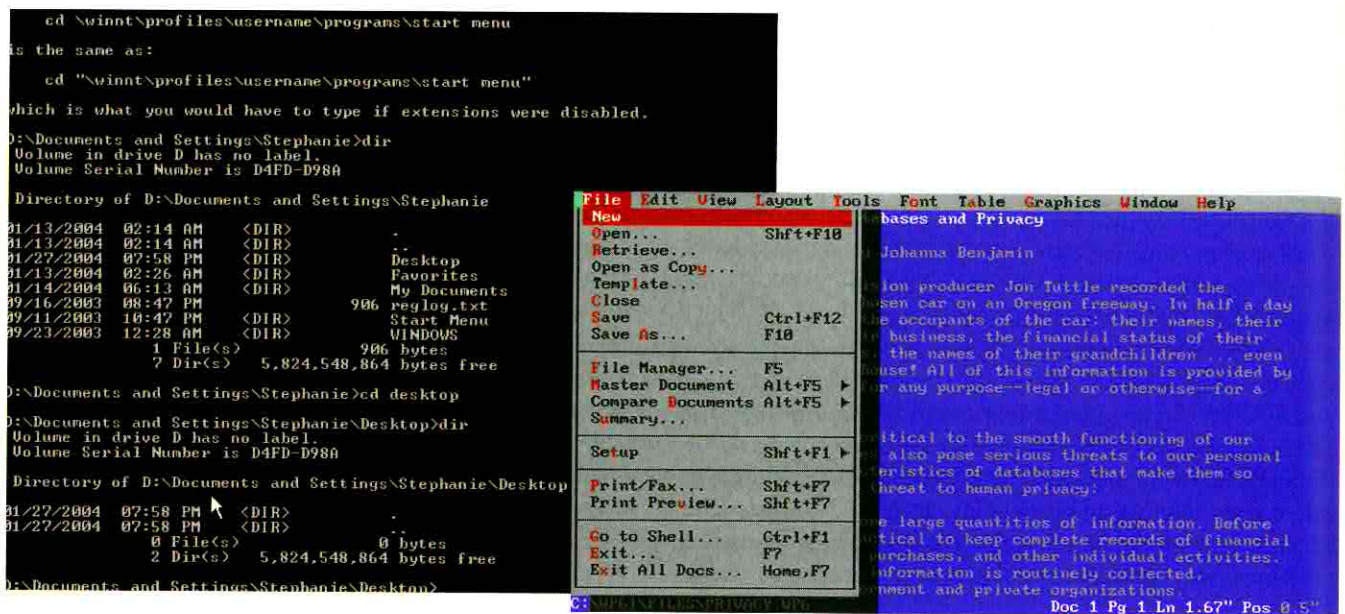


FIGURE 4.19 When typing commands to the OS or selecting options from menus in applications, MS-DOS users work with a character-based interface.



FIGURE 4.20 Many consumer devices today, including VCRs, cell phones, and pagers, have character-based user interfaces.

have a **menu-driven interface** that enabled users to choose commands from on-screen lists called **menus**.

In the years since the introduction of the original IBM PC, graphic displays have become the norm. A computer with a graphic display is not limited to displaying rows and columns of characters; it can individually control every dot on the screen. When the Apple Macintosh was introduced in 1984, it was the first low-cost computer that had an operating system designed with a **graphical user interface**—abbreviated **GUI**, and pronounced “goeey.” The **Mac OS**, however, was eclipsed by a product from Microsoft, the company that produced MS-DOS. Today **Microsoft Windows** is far and away the most popular operating system for PCs.



FIGURE 4.21 Mac OS X refines the traditional graphical user interface with a modern take on windows, icons, and directories.

Windows and the Mac OS have evolved over the years, adding new features to their GUIs to make them easier to use. The Windows **taskbar** provides one-click access to open applications, making it easy to switch back and forth among different tasks. **Hierarchical menus** in Windows and Mac OS organize frequently needed commands into compact, efficient submenus, and **pop-up menus** can appear anywhere on the screen. **Context-sensitive menus** offer choices that depend on which on-screen object the user has currently selected.

While there are many differences between Windows and Mac OS, the two now have user interfaces that are more alike than different. Many applications, including Adobe Photoshop and Microsoft Office, are almost identical on Windows and the Mac OS.

Both Windows and the Mac OS started as single-user operating systems. But today both support multiple users. Both are available in server versions that can be used as alternatives to UNIX, the OS that has ruled the server market for decades. (For a more thorough introduction to Windows and Mac OS, see Appendix A).

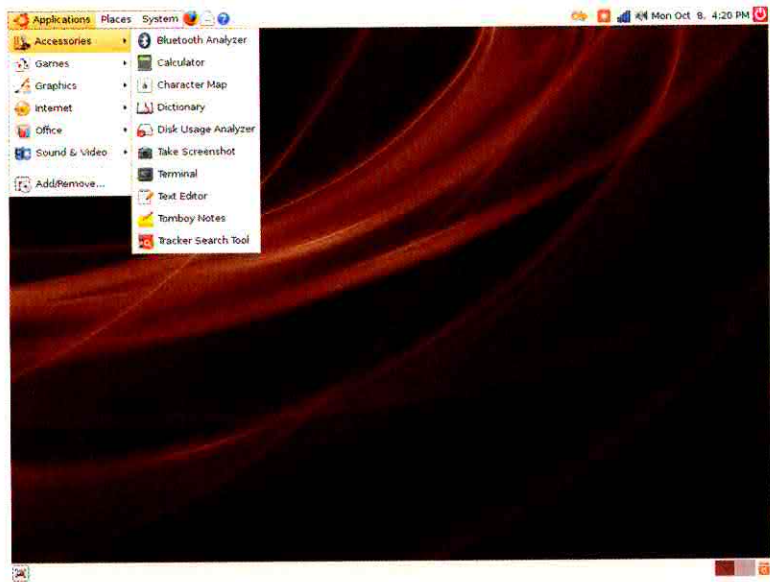


FIGURE 4.22 Many versions of Linux, including Ubuntu Linux, use menus and icons in ways that would be familiar to Windows and Macintosh users.

UNIX and Linux

Because of its historical ties to academic and government research sites, the Internet is still heavily populated with computers running the **UNIX** operating system. UNIX, developed at Bell Labs more than a decade before the first PCs, enables a timesharing computer to communicate with several other computers or terminals at one time. UNIX has long been the operating system of choice for workstations and mainframes in research and academic settings. In recent years it has taken root in many business environments. In spite of competition from Microsoft, UNIX is still favored by many who require an industrial-strength, multi-user operating system. Some form of UNIX is available for personal computers, workstations, servers, mainframes, and supercomputers.

Because of widespread licensing, commercial brands of UNIX are available from many companies, including Sun (Solaris), Hewlett-Packard (HP-UX), and IBM (AIX). Most Mac users don't know it, but Mac OS X is built around a version of UNIX. Linux, a UNIX clone described at the beginning of this chapter, is widely distributed for free and supported without cost by a devoted, technically savvy group of users.

At its heart, in all its versions, UNIX is a command-line, character-based operating system. The command-line interface (or **shell**) is similar to that of MS-DOS, although the commands aren't the same. For most tasks the UNIX command-line interface feels like a single-user system, even when many users are **logged in**—connected to and using the system. But today's UNIX systems work

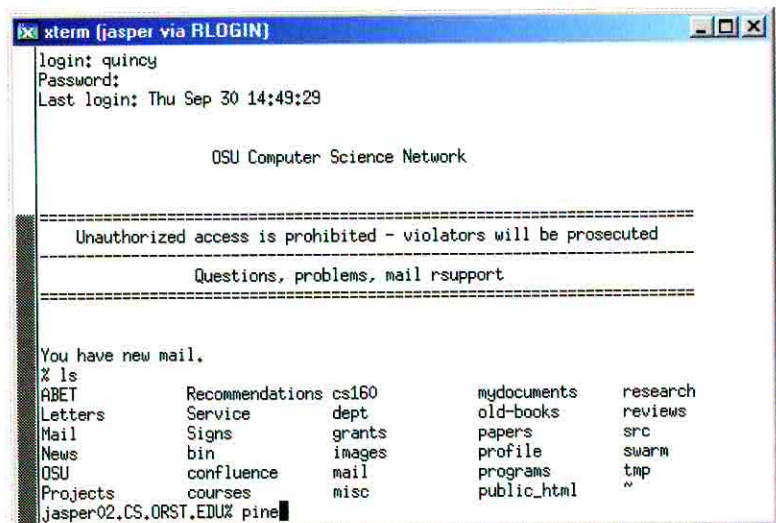


FIGURE 4.23 In its basic form, UNIX is a character-based operating system. This screen shows the beginning of a session on a school's multi-user UNIX mainframe. After the user (quincy) types his login name and password, the system responds with some introductory messages and a prompt (in this case, %). Quincy types the "ls" command to view the names of files in his home directory. The system lists the files and displays a new prompt. Quincy types "pine" to run the pine email program. The session continues this way until quincy responds to a prompt with a command to log off the system. In practice, many UNIX users never see this type of command-line interface because of software shells with GUIs similar to Windows or Mac OS.

with more than just typed commands. Several companies, including Apple, Sun, and IBM, market UNIX variations and shells with graphical interfaces.

Hardware and Software Platforms

In most electronic devices, the operating system operates invisibly and anonymously. But some operating systems, especially those in PCs, are recognized by name and reputation. The most well-known operating systems include:

- **Microsoft Windows Vista.** This is Microsoft's flagship product. Microsoft sells five different versions of Vista, including Vista Home Basic, for simple home computing needs; Vista Home Premium, which includes Windows Media Center software; Vista Business, for business users; Vista Enterprise, for global organizations with complex IT infrastructures; and Vista Ultimate, the most feature-rich version of the operating system, with capabilities for home computing, mobile computing, and entertainment. All versions share the same code base. Windows Vista is distinguished from earlier versions of Windows by a new user interface, refined navigation and searching tools, beefed-up security, and somewhat slower performance (on many older PCs).

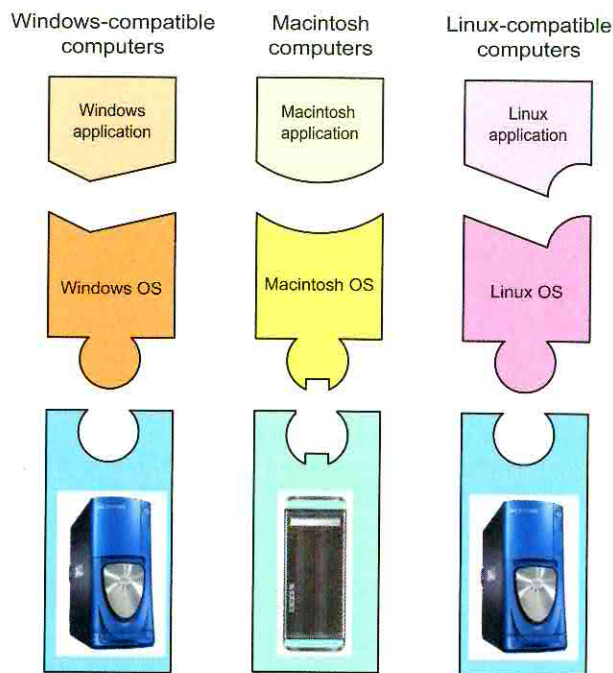


FIGURE 4.25 Compatibility issues: Applications are designed to run on particular operating systems. Operating systems are designed to run on particular hardware platforms.

- **Microsoft Windows Server 2008.** Essentially the server-based counterpart to Windows Vista, this version of Windows runs on everything from small Web servers to the mightiest hardware on the planet. This product competes with UNIX and Linux.
- **Microsoft Windows XP.** Windows XP was Microsoft's principal operating system from 2001 until 2006. Microsoft based Windows XP on an earlier operating system that was called Windows NT.
- **Windows Embedded CE.** This stripped-down Windows variant is designed for embedded, connected devices, such as robots, voting machines, music players, and medical equipment. Another Windows CE-based operating system, called Windows Mobile, targets cell phones and Pocket PCs, which means it competes directly with Palm's operating system.
- **Mac OS X (10).** OS X is the standard operating system for the Mac. It sports a stylish, animated user interface that makes many complex tasks surprisingly simple to accomplish. Underneath its friendly exterior, OS X is built on UNIX, the powerful OS known for security and stability rather than simplicity. OS X runs on all modern Macs. A tiny variant of OS X is installed in the iPhone. Apple has released several major upgrades to OS X since its 2001 introduction. Each upgrade has a unique decimal number and informal name. For example, the version introduced in 2007 is known both as OS X 10.5 and as Leopard.
- **Mac OS 9.** This is the last in a long line of Mac operating systems that started with the original Mac system in 1984. OS 9 and its predecessors run only on older Macs.
- **Linux, Sun Solaris, and other UNIX variations.** Some forms of UNIX or Linux can be found on PCs, Macs, workstations, supercomputers, mainframes, and a variety of other devices. Linux is especially popular because it is free—and freely supported by its partisans. Because Linux doesn't offer as many application programs as Windows does, some people use *dual-boot PCs* that can switch back and forth between Windows and Linux by simply rebooting.
- **BlackBerry OS.** The BlackBerry is a wireless personal digital assistant (PDA) manufactured by Canadian company Research in Motion (RIM). The BlackBerry is especially popular with travellers who want to access email everywhere. The BlackBerry has a proprietary multitasking operating system that supports wireless communication with PCs and takes advantage of the PDA's unique input devices, especially its thumbwheel.
- **Palm OS.** This OS is used in many PDAs and smart phones. It has communication capabilities that make it easy to transfer data between a Palm device and another computer.